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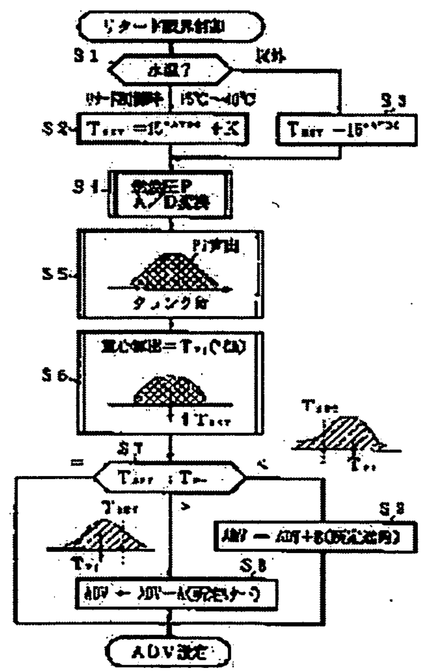
(54) COMBUSTION CONDITION DETECTING DEVICE FOR INTERNAL COMBUSTION ENGINE AND CONTROL DEVICE FOR INTERNAL COMBUSTION ENGINE UTILIZING THE DEVICE



(57)Abstract:

PURPOSE: To achieve a desired combustion condition, and promote activation of an exhaust purifying catalyst in an early stage.

CONSTITUTION: It is judged whether an engine cooling water temperature is in a prescribed range or not (S1), and advance to S2 when it is in the prescribed range. Advance to S3 when it is not in the prescribed range. At the S2, set a target combustion gravity center position which is obtained when an ignition timing is delay-angle-controlled to TSET. At S3, set the target combustion gravity center position which is obtained when a normal ignition timing is controlled to TSET. At S4 to S6, find out the gravity center position Tpi of present combustion on the basis of detected combustion pressure. At S7, compare the Tpi with TSET, and feed back-control an ignition timing so as to set the present combustion gravity center position Tpi to the target combustion gravity center position TSET at S8, S9. It is thus possible to fasten activation of the catalyst after starting to a maximum limit, since the ignition timing is feed back- controlled with high accuracy so as to obtain a desired combustion condition per engine or per cylinder.

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CLAIMS

[Claim(s)]
[Claim 1] The combustion condition detection equipment of the internal combustion engine which characterizes by to have constituted including a firing-pressure detection means detect a firing pressure, a combustion center-of-gravity location detection means ask for a location as a combustion center-of-gravity location based on said detected firing pressure whenever [equivalent to the center of gravity of the combustion during a combustion period / crank-angle], and a combustion condition detection means detect a combustion condition based on said detected combustion center-of-gravity location.
[Claim 2] A firing-pressure detection means to detect a firing pressure, and a combustion center-of-gravity location detection means to ask for a location as a combustion center-of-gravity location based on said detected firing pressure whenever [equivalent to the center of gravity of the combustion during a combustion period / crank angle], So that said combustion center-of-gravity location may serve as a target center-of-gravity location means to set up a location as a target center-of-gravity location whenever [equivalent to the center of gravity of the combustion during a combustion period when a desired combustion condition is acquired / crank angle] in said target center-of-gravity location, according to operational status The control unit of the internal combustion engine characterized by constituting an engine controlled variable including the engine controlled-variable feedback control means which carries out feedback control.
[Claim 3] The control unit of the internal combustion engine according to claim 2 characterized by for a combustion line to more nearly usually bring from the time the target center-of-gravity location set up by said target center-of-gravity location means close to a termination side when it has a catalytic activity condition detection means detect the active state of the exhaust air purification catalyst infixed in the engine exhaust air system and catalyst inactive is detected by said catalytic activity condition detection means.
[Claim 4] The control unit of the internal combustion engine according to claim 2 or 3 with which said engine controlled variable is characterized by being ignition timing.
[Claim 5] Combustion condition detection equipment of the internal combustion engine characterized by having equipment according to claim 1 for every gas column.
[Claim 6] The control unit of the internal combustion engine characterized by having equipment of any one publication of claim 2 - claim 4 for every gas column.

[Translation done.]

* NOTICES *

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the control unit of the internal combustion engine having an internal combustion engine's combustion condition detection equipment and its equipment. In detail, it is related with amelioration of the control unit of the internal combustion engine which controls an engine controlled variable based on the improved detection technique concerned, concerning amelioration of the detection technique an internal combustion engine's combustion condition.
[0002]
[Description of the Prior Art] Reducing the discharge of the exhaust air injurious ingredients (NOx, CO, HC, etc.) from an after [starting] early stage to the inside of atmospheric air from the former, as the exhaust air purification catalyst infixed in an internal combustion engine's exhaust air system is activated from an after [engine starting] early stage is performed. As the example, by carrying out the constant-rate lag of the ignition timing for example, within an after [engine starting] predetermined period, a combustion condition is worsened, an exhaust-gas temperature is raised, and there are some which are going to attain early activation of an exhaust air purification catalyst by this.
[0003]
[Problem(s) to be Solved by the Invention] However, by the above-mentioned conventional approach, even if the exhaust-gas temperature (change of a combustion condition) for every gas column of an engine to the lag of ignition timing gives the amount of the said lags uniformly, since inhalation-of-air flow, such as a compression ratio, an intake air flow, and a swirl, differs from valve timing etc. for every gas column, they will differ for every gas column of the in fact. Of course, since the variation between engines also exists, in the amount of lags of a constant rate, there is same problem also in every engine.
[0004] ** That is, in the uniform amount of lags, since the gas column in which combustion gets worse was in the degree of pole and variation would arise between the gas columns of many gas columns which still have allowances till a critical point existing (or between engines) if it is going to avoid this, an exhaust-gas temperature was not able to be raised effectively. Therefore, it is desirable that it is made to carry out the lag of the ignition timing for every (every [or] engine) gas column till the critical point which can carry out the maximum lag, securing the stability limit of combustion at the point that an exhaust-gas temperature can be raised effectively, securing operability, fuel consumption, an exhaust air property, etc. to predetermined within the limits.
[0005] In addition, the problem by the variation between these gas columns and between engines is similarly generated, not only lag control of ignition timing but when it controls at the ignition timing set up noting that the desired combustion condition was acquired. That is, in spite of having controlled at the ignition timing set up noting that the desired combustion condition was acquired, it is because the gas column from which a desired combustion condition is not acquired in fact will occur by the variation between gas columns and between engines.
[0006] ** Although there is the approach of carrying out the lag of the ignition timing till a critical point for every (every engine) gas column there that the problem of the above-mentioned ** should be solved, for example, cylinder internal pressure is measured for every gas column (a 1 cylinder is

sufficient when abolishing the variation between engines), it asks for indicated mean effective pressure (it is also called IMEP and Following Pi), and there are some which find out a critical point based on fluctuation of this Pi value.
[0007] however -- as this Pi value is a value which asked for the area of the section whenever [predetermined crank angle / of combustion pressure (cylinder internal pressure)] and is shown in drawing 7 , even if it carries out the lag of the ignition timing -- the Pi value itself -- it was what cannot detect the critical point of an ignition timing lag with high precision even if it does not change a lot and detects [therefore] fluctuation of Pi value. Moreover, rotation fluctuation is detected, and since the direct combustion condition is not detected, the critical point of an ignition timing lag is undetectable in this case, although there are some which find out the critical point of an engine's ignition timing lag based on that result with high precision.
[0008] In addition, it does not restrict for finding out the critical point of an ignition timing lag in this way, but combustion stability (namely, Pi fluctuation) is detected from indicated mean effective pressure Pi, and since the fluctuation of the Pi value itself is small when carrying out feedback control of the ignition timing so that predetermined stability may be obtained, there is a problem that control precision becomes [detection precision] low low. This invention is what was made in view of the conventional actual condition indicated to the above-mentioned ** and **. As opposed to the combustion condition detection technique first based on the conventional Pi fluctuation etc. to the 1st As a desired combustion condition acquired in the 2nd from a. using the b. above-mentioned combustion condition detection equipment for the purpose of offering the combustion condition detection equipment of the internal combustion engine which can detect a combustion condition to high degree of accuracy It aims at offering the control unit of the internal combustion engine which does feedback control of the ignition timing (however, you may be engine controlled variables, such as not only this but the fuel amount of supply, a supply stage, the amount of EGR(s), etc.).
[0009] in addition, using the above-mentioned control unit, a combustion condition is carried out near the critical point at the time of catalyst inactive, and an exhaust-gas temperature is gone up -- making -- with -- **** -- while aiming at attaining early activation of an exhaust air purification catalyst, and being able to be made to carry out the maximum reduction of the discharge of an exhaust air injurious ingredient, it aims at aiming at improvement in further detection precision, control precision, etc. by forming each above-mentioned equipment for every gas column.
[0010]
[Means for Solving the Problem] Therefore, the combustion condition detection equipment of the internal combustion engine concerning invention of claim 1 A firing-pressure detection means to detect a firing pressure as shown in drawing 1 , and a combustion center-of-gravity location detection means to ask for a location as a combustion center-of-gravity location whenever [crank angle / which is equivalent to the center of gravity of the combustion during a combustion period based on said detected firing pressure], Based on said detected combustion center-of-gravity location, it constituted including a combustion condition detection means to detect a combustion condition.
[0011] The control unit of the internal combustion engine concerning invention according to claim 2 A firing-pressure detection means to detect a firing pressure as shown in drawing 2 , and a combustion center-of-gravity location detection means to ask for a location as a combustion center-of-gravity location whenever [crank angle / which is equivalent to the center of gravity of the combustion during a combustion period based on said detected firing pressure], So that said combustion center-of-gravity location may serve as a target center-of-gravity location means to set up a location as a target center-of-gravity location whenever [equivalent to the center of gravity of the combustion during a combustion period when a desired combustion condition is acquired / crank angle] in said target center-of-gravity location, according to operational status The engine controlled variable was constituted including the engine controlled-variable feedback control means which carries out feedback control.
[0012] In addition, when it had a catalytic activity condition detection means to detect the active state of the exhaust air purification catalyst infixed in the engine exhaust air system and catalyst inactive was detected by said catalytic activity condition detection means, the combustion line constituted the target center-of-gravity location set up by said target center-of-gravity location means

from invention according to claim 3 so that it might usually bring close to a termination side from the time.

[0013] Said engine controlled variable consisted of invention according to claim 4 as ignition timing. Claims 5 and 6 were equipped with each above-mentioned equipment for every gas column by invention of a publication.

[0014]

[Function] With the combustion condition detection equipment of the internal combustion engine concerning invention according to claim 1 The center-of-gravity location of the combustion during the combustion period which changes comparatively a lot to change of a combustion condition, Namely, whenever [crank angle / of the change pattern in the combustion periods (the combustion pressure itself, indicated mean effective pressure or a heat rate, etc.) of the value correlated with combustion pressure], or the center-of-gravity location to time amount, It detects and a combustion condition is detected based on the detected combustion center-of-gravity location concerned (by for example, thing compared with the target center-of-gravity location corresponding to the predetermined combustion condition defined beforehand). Thereby, compared with what detects a combustion condition based on fluctuation of the indicated mean effective pressure which appears only as a comparatively small change to change of a combustion condition etc., an engine's combustion condition is more detectable to high degree of accuracy like before. In addition, what equalized the center-of-gravity location of not only the thing of 1 combustion cycle but two or more combustion cycle is sufficient as a combustion center-of-gravity location.

[0015] Even if there is variation between engines, a target combustion condition can be made to attain with high precision in the control unit of the internal combustion engine concerning invention according to claim 2, since it was made to carry out feedback control of the engine controlled variable so that the combustion center-of-gravity location detected by the above-mentioned approach might be in agreement with a target center-of-gravity location. For example, if ignition timing is controlled so that combustion energy turns into exhaust air energy within a predetermined combustion stability limit at max, if it is in the ignition timing lag control for the catalyst early activation after engine starting, and it is usually in ignition timing control, it is controlling ignition timing so that combustion energy may turn into rotational energy effectively, and a desired combustion condition can be attained. In addition, as well as between engines, even if there is variation between gas columns, a target combustion condition can be made to attain for every gas column with high precision like invention according to claim 5, if the above-mentioned control is performed in each gas column.

[0016] since a combustion condition can be worsened to a request at the time of catalyst inactive [after starting etc.] since the combustion line more nearly usually brought said target center-of-gravity location close to a termination side from the time, and an exhaust-gas temperature can be effectively raised in a catalyst inactive condition in invention according to claim 3 -- with -- **** -- activation of a catalyst can be promoted effectively and discharge of an exhaust air injurious ingredient can be stopped to min.

[0017] In invention according to claim 4, it becomes possible to control in the target combustion condition often [responsibility] and with high precision, since said engine controlled variable was constituted as ignition timing.

[0018]

[Example] Below, one example of this invention is explained. In drawing 3 which is the system schematic diagram of the example concerning this invention, air is inhaled by the 4-cylinder internal combustion engine 1 through an air cleaner 2, the throttle chamber 3, and an inlet manifold 4. And the combustion exhaust air from an engine 1 is discharged in atmospheric air through an exhaust manifold 5, a jet pipe 6, the three way component catalyst 7 as an exhaust air purification catalyst, and muffler 8 grade. In addition, although this example explains using a three way component catalyst 7, you may have not only this but an oxidation catalyst, the Lean NOx catalyst, etc.

[0019] The throttle valve 9 which is interlocked with the accelerator pedal which is not illustrated, and is opened and closed is formed in said throttle chamber 3, and an engine's 1 inhalation air content is adjusted to it by this throttle valve 9. Moreover, although the combustion chamber of each gas column (#1-#4) is made to attend and it is equipped with the ignition plug (illustration

abbreviation), respectively, the cylinder internal pressure sensors 10a-10d are formed in this ignition plug and pair for every gas column.
[0020] Said cylinder internal pressure sensors 10a-10d may be things of a type which are made to face [a direct combustion chamber] the sensor section which is indicated by JP,4-81557,A besides the type with which it is equipped as a washer of an ignition plug which is indicated by JP,63-17432,U, and detect cylinder internal pressure. In addition, what is necessary is just to attach a cylinder internal pressure sensor in any 1 cylinder, in aiming at abolishing the variation between engines.
[0021] Moreover, the crank angle sensor 11 which detects a crank angle through rotation of a cam shaft is formed in the cam shaft which an engine 1 does not illustrate. This crank angle sensor 11 is a sensor which outputs the criteria include-angle signal REF of every [equivalent to the stroke phase contrast between gas columns] crank angle 180 **, and the unit include-angle signal POS for every unit crank angle, respectively in the 4-cylinder engine 1 of this example.
[0022] In addition, the detecting signal corresponding to a specific 1 cylinder can distinguish now said criteria include-angle signal REF from other detecting signals with the pulse width etc. at least so that gas column distinction can be performed. Moreover, the air flow meter 13 which detects an engine's 1 intake air flow Q is formed in the upstream of said throttle valve 9, and the potentiometer-type throttle sensor 14 which detects the opening TVO of this throttle valve 9 is formed in said throttle valve 9.
[0023] Furthermore, the coolant temperature sensor 15 which detects an engine's 1 circulating water temperature is formed. The output of said cylinder internal pressure sensors 10a-10d, the 11 air flow meter crank angle sensor 13, the throttle sensor 14, and coolant temperature sensor 15 grade is outputted to the control unit 12 prepared as an object for engine control. Said control unit 12 which built in the microcomputer detects operational status based on these input signals, and it controls the ignition timing by the ignition plug while it controls the fuel oil consumption by the fuel injection valve which is not illustrated, and fuel injection timing corresponding to this.
[0024] Here, the ignition timing control (combustion condition detection control is included) which the control unit 12 in this example performs is explained with reference to the flow chart of drawing 4 . In addition, in this example, the control unit 12 is equipped with each function as a firing-pressure detection means, a combustion center-of-gravity location detection means, a combustion condition detection means, a target center-of-gravity location means, an engine controlled-variable feedback control means, and a catalytic activity condition detection means by software.
[0025] It sets to the flow chart of drawing 4 , and is a step (referred to as S by a diagram.). By 1, the engine cooling water temperature which the coolant temperature sensor 15 detected judges like the following whether it is in the predetermined range (for example, 15-40-degreeC). If it is YES, it will progress to step 2 in order to perform the ignition timing lag for catalyst early activation. If it is NO, it will progress to step 3. namely, from the predetermined range, it is the condition [which carried out after / starting / predetermined period progress], or restart time etc., and, as for an elevated-temperature side, engine temperature has also already activated the three way component catalyst 7 highly (or it is in the condition of being very easy to be activated) -- ** -- since it is not necessary to judge and to perform lag control in this case, priority is given to operability, fuel consumption, etc. -- it is made to progress to step 3 in order to make it usually control And it is made to progress to step 3 in order to forbid lag control also in this case and to give priority to operability over the predetermined range, since operability (combustion stability) will get worse exceeding a tolerance limit, if lag control is performed at the time of the very low temperature by the side of low temperature. The step 1 concerned functions as a catalytic activity condition detection means of this invention.
[0026] In order to make lag control of the ignition timing for catalytic activity-ized promotion perform at step 2, it is TSET whenever [target center-of-gravity crank angle]. It sets to "15(deg ATDC) +K." In addition, TSET =15 (deg ATDC) is an example from which MBT (Minimum Spark Advancefor Best Torque) is obtained, and K shows the amount of marginal lag setup by the side of ATDC (after a top dead center). TSET and K are every engine and the value of the request set up for every service condition whenever [this target center-of-gravity crank angle]. In addition, it is TSET whenever [here target center-of-gravity crank angle]. It is the value beforehand checked by

experiment etc., and is whenever [corresponding to the center-of-gravity location of the generating pattern of the indicated mean effective pressure in the combustion period acquired when ignition timing is set as a critical point / crank angle].
[0027] In order to make ignition timing control usually perform at step 3, it is TSET whenever [target center-of-gravity crank angle]. For example, it sets to 15 (deg ATDC) (it will control to MBT). It is TSET whenever [here target center-of-gravity crank angle]. It is the value beforehand checked by experiment etc., and is whenever [corresponding to the center-of-gravity location of the generating pattern of the indicated mean effective pressure in the combustion period acquired when ignition timing is set as MBT / crank angle].
[0028] The above-mentioned steps 2 and 3 function as a target center-of-gravity location means of this invention. At step 4, A/D conversion of the detecting signal of cylinder internal pressure sensor 10a (or 10b-10d) is carried out. In addition, it is [the step after the step 4 concerned] most accurate that it is made to perform for every gas column. The step 4 concerned is equivalent to a firing-pressure detection means. At step 5, as shown in a flow, indicated mean effective pressure (Pi) is computed by the well-known approach using the result obtained at step 4. As for the section, it is [whenever / crank angle / which is used for this calculation of Pi] desirable to limit to the section (that is, for a pumping stroke etc. to be removed) influenced of combustion pressure in respect of computation time, memory space, etc.
[0029] At step 6, as shown in a flow, Tpi (deg CA) is calculated whenever [corresponding to the center-of-gravity location of the indicated mean effective pressure (IMEP) computed at step 5 / actual crank angle]. The calculation approach of this center-of-gravity location may be a well-known approach. Steps 5 and 6 are equivalent to the combustion center-of-gravity location detection means of this invention. In addition, you may make it ask for the center-of-gravity location of a raw wave (or wave after A/D conversion) in the combustion period of the cylinder internal pressure P, and may make it ask for the center-of-gravity location in quest of a heat rate pattern.
[0030] It is TSET whenever [target center-of-gravity crank angle / which was set at step 2 or step 3 in step 7]. Tpi is compared whenever [actual center-of-gravity location crank angle]. a target center-of-gravity location's of current Pi combustion [/ a target center-of-gravity location]-good condition if it is TSET =Tpi -- if it puts in another way, it will judge that target ignition timing is obtained and this flow will be ended.
[0031] TSET > If it is Tpi, it judges that the center-of-gravity location of current Pi is in a top dead center (TDC) side to a target center-of-gravity location, and the target combustion condition will still be reached, and it will judge that there is nothing (the lag of the ignition timing has not been carried out till the target critical point if it puts in another way), will progress to step 8, and will carry out a specified quantity A lag (retard) to the current ignition timing ADU, and this flow will be ended.
[0032] On the other hand, if it is TSET </SUB> <Tpi, it judges that the center-of-gravity location of current Pi is in a bottom dead point (BDC) side to a target center-of-gravity location, and it will judge that it got worse exceeding the target combustion condition (the lag of the ignition timing was carried out too much, and the target critical point was crossed when putting in another way), will progress to step 9, and will carry out a specified quantity B tooth lead angle (advance) to the current ignition timing ADU, and this flow will be ended. In addition, said A and B may be tales doses and may be changed. However, A<=B is desirable if engine stability is taken into consideration.
[0033] The above-mentioned step 7 is equivalent to the combustion condition detection means of this invention. thus, the indicated mean effective pressure in "combustion period which changes comparatively a lot to change of a combustion condition according to this example (or a combustion pressure wave --) Target center-of-gravity location TSET which detected the center-of-gravity location Tpi of the generating pattern of a heat rate", and was beforehand determined as the detected center-of-gravity location Tpi concerned Since the combustion condition was detected by comparing Compared with what detects a combustion condition based on fluctuation of Pi etc. like before, an engine's combustion condition is more detectable to high degree of accuracy.
[0034] moreover, this detected center-of-gravity location Tpi is in agreement with the target center-of-gravity location TSET -- as (if it is in the ignition timing lag control for the catalyst early activation after engine starting, combustion energy turns into exhaust air energy within a predetermined combustion stability limit at max -- as .) Usually, if it is in ignition timing control,

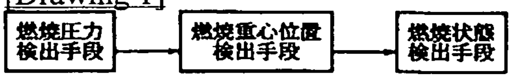
combustion energy should turn into rotational energy effectively. Even if there are variation between engines and variation between gas columns, a target combustion condition can be made to attain with high precision, since it was made to carry out feedback control of the ignition timing.
[0035] In addition, in this example, in a catalyst inactive condition, since it was made to make lag control of the ignition timing by the above-mentioned approach perform, since the early activity of a three way component catalyst 7 can be effectively promoted in after starting etc., discharge of an exhaust air injurious ingredient can be reduced from the early stage after starting, for example. By the way, although the catalyst inactive condition was detected based on cooling water temperature, except for the time of very low temperature, it may be made for it to be made to carry out direct detection of whenever [catalyst temperature], and to carry out a legal fiction in this example, within the predetermined period beforehand defined after starting (for example, when for water temperature to be lower than 15 degrees) to a catalyst being in an inactive condition. Moreover, at the time of starting, when it is very low temperature, after [starting] predetermined period usual control is performed, and lag (retard) control of ignition timing can be performed within a predetermined period after that (refer to drawing 6).
[0036] Moreover, although explained on behalf of ignition timing as a factor which controls a combustion condition (since control is comparatively easy and responsibility is high), you may make it control the fuel amount of supply, a fuel-supply stage, an intake air flow (for the fuel amount of supply to be fixed in this case), the amount of EGR(s), the amount of purge gas, etc. by this example.

[0037]
[Effect of the Invention] Since the center-of-gravity location of the combustion during the combustion period which changes comparatively a lot to change of a combustion condition detects and the combustion condition detected based on the detected combustion center-of-gravity location concerned according to the combustion condition detection equipment of the internal combustion engine concerning invention of claim 1 as explained above, an engine's combustion condition is detectable with high precision.
[0038] Even if there is variation between engines, a target combustion condition can be made to attain with high precision, since according to the control unit of the internal combustion engine concerning invention according to claim 2 it was made to carry out feedback control of the engine controlled variable so that the combustion center-of-gravity location detected by the above-mentioned approach might be in agreement with a target center-of-gravity location. In addition, as well as between engines, even if there is variation between gas columns, a target combustion condition can be made to attain for every gas column with high precision like invention according to claim 5, if the above-mentioned control is performed in each gas column.
[0039] Since the combustion line more nearly usually brought said target center-of-gravity location close to a termination side from the time in the catalyst inactive condition according to invention according to claim 3 since a combustion condition can be worsened to a request and an exhaust-gas temperature can be effectively raised at the time of catalyst inactive [after starting etc.] -- with -- **** -- activation of a catalyst can be promoted effectively and discharge of an exhaust air injurious ingredient can be stopped to min.
[0040] According to invention according to claim 4, it becomes possible to control in the target combustion condition often [responsibility] and with high precision, since said engine controlled variable was constituted as ignition timing.

[Translation done.]

DRAWINGS

[Drawing 1]



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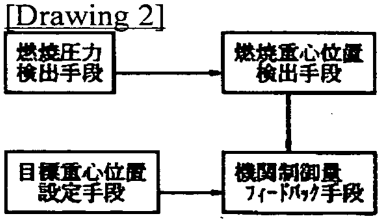

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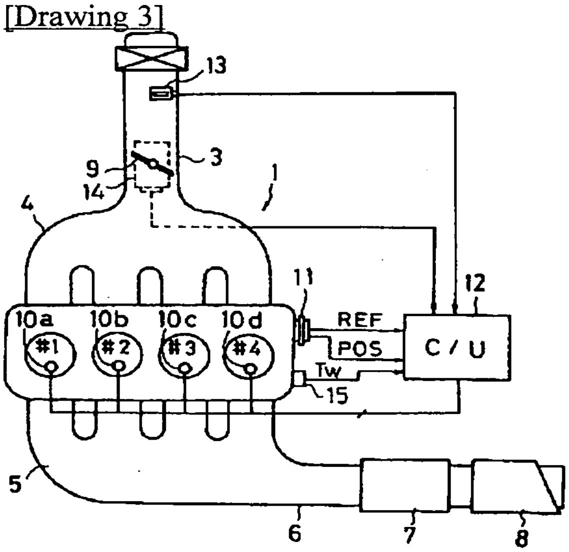

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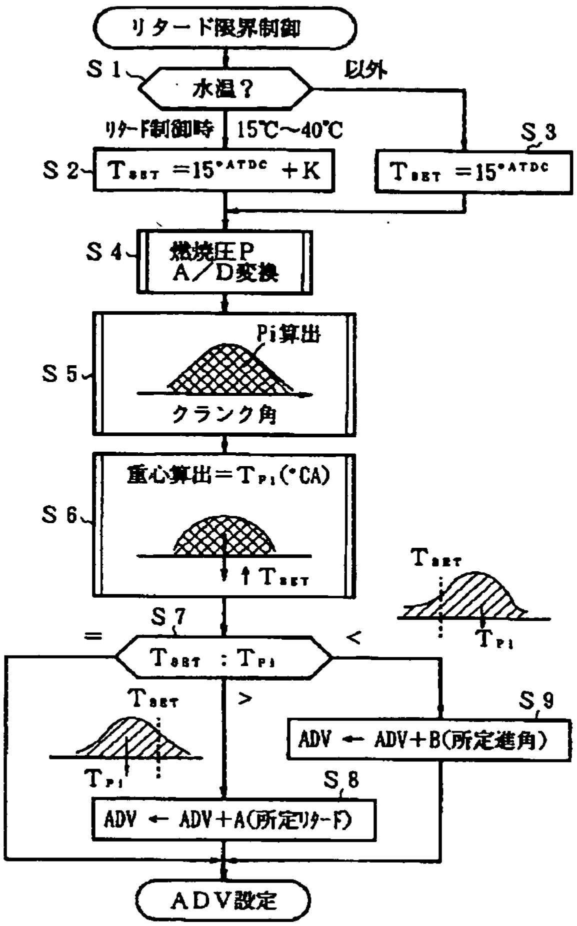

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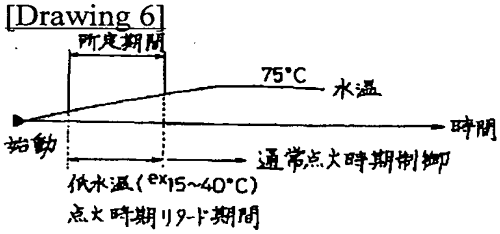

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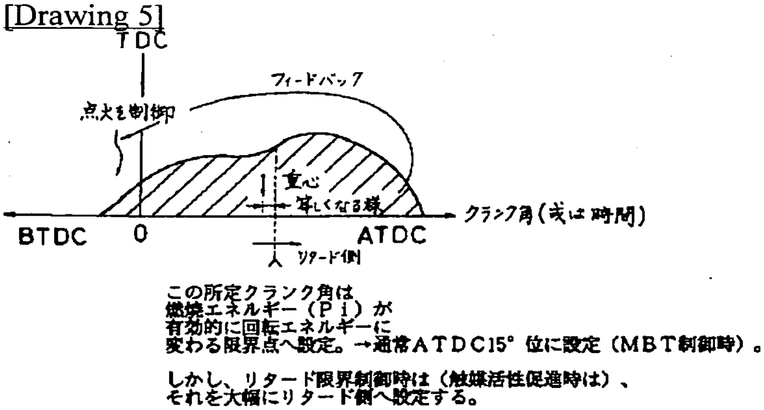

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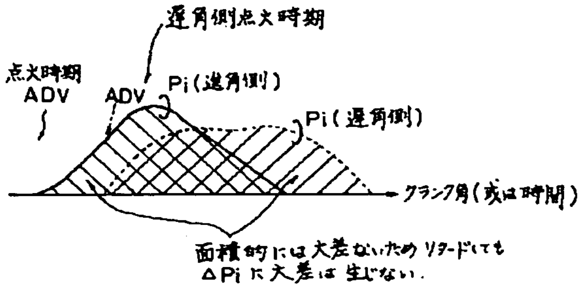

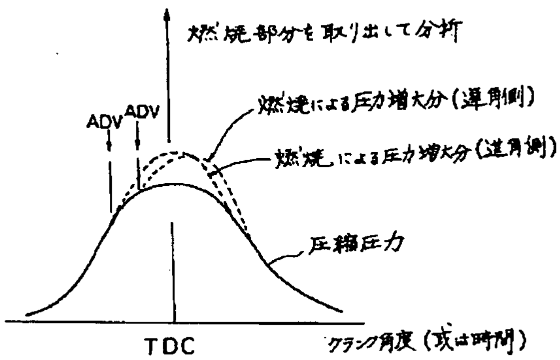

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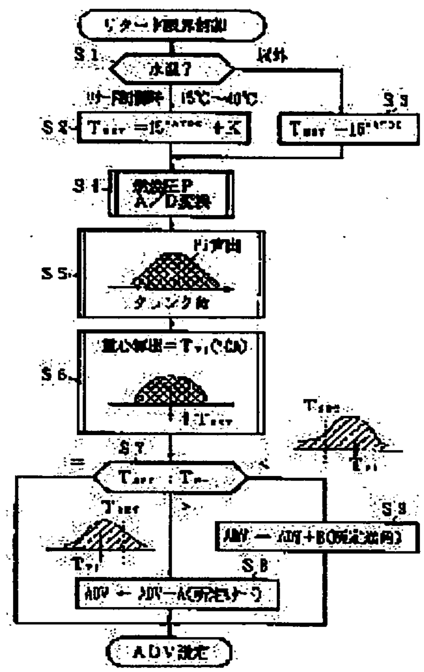
(54) COMBUSTION CONDITION DETECTING DEVICE FOR INTERNAL COMBUSTION ENGINE AND CONTROL DEVICE FOR INTERNAL COMBUSTION ENGINE UTILIZING THE DEVICE

(57)Abstract:
PURPOSE: To achieve a desired combustion condition, and promote activation of an exhaust purifying catalyst in an early stage.
CONSTITUTION: It is judged whether an engine cooling water temperature is in a prescribed range or not (S1), and advance to S2 when it is in the prescribed range. Advance to S3 when it is not in the prescribed range. At the S2, set a target combustion gravity center position which is obtained when an ignition timing is delay-angle-controlled to TSET. At S3, set the target combustion gravity center position which is obtained when a normal ignition timing is controlled to TSET. At S4 to S6, find out the gravity center position Tpi of present combustion on the basis of detected combustion pressure. At S7, compare the Tpi with TSET, and feed back-control an ignition timing so as to set the present combustion gravity center position Tpi to the target combustion gravity center position TSET at S8, S9. It is thus possible to fasten activation of the catalyst after starting to a maximum limit, since the ignition timing is feed back- controlled with high accuracy so as to obtain a desired combustion condition per engine or per cylinder.



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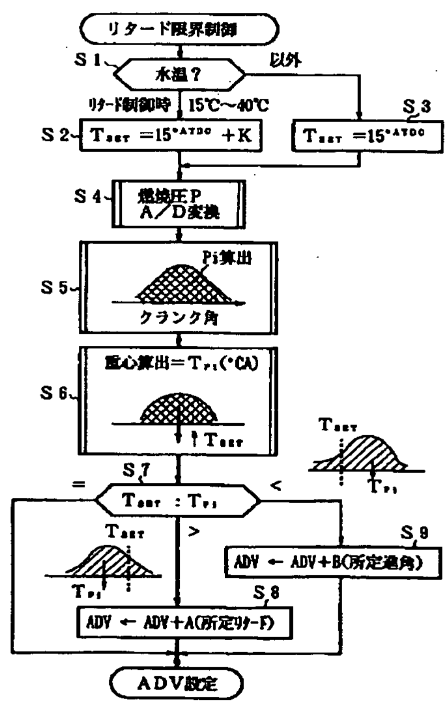
(54)【発明の名称】　内燃機関の燃焼状態検出装置及びその装置を利用した内燃機関の制御装置

(57)【要約】

【目的】所望の燃焼状態を達成し、排気浄化触媒の早期活性化を促進すること。

【構成】機関冷却水温が所定範囲内にあるか否かを判断し（Ｓ１）、所定範囲内のときにはＳ２へ進む。所定範囲外のときはＳ３へ進む。Ｓ２では、T_{SET}に点火時期の遅角制御を行なった場合に得られる目標の燃焼重心位置をセットする。Ｓ３では、T_{SET} に通常の点火時期制御を行なった場合に得られる目標の燃焼重心位置をセットする。Ｓ４～Ｓ６で、検出された燃焼圧に基づき現在の燃焼の重心位置Ｔｐｉを求める。Ｓ７では、ＴｐｉとT_{SET} とを比較し、Ｓ８，Ｓ９で、現在の燃焼重心位置Ｔｐｉが目標の燃焼重心位置T_{SET} となるように点火時期をフィードバック制御する。これにより、機関毎或いは気筒毎に所望の燃焼状態が得られるように、高精度に点火時期をフィードバック制御することができるので、始動後の触媒の早期活性化を最大限早めることも可能となる。



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【特許請求の範囲】

【請求項１】燃焼圧力を検出する燃焼圧力検出手段と、前記検出された燃焼圧力に基づいて、燃焼期間中の燃焼の重心に相当するクランク角度位置を燃焼重心位置として求める燃焼重心位置検出手段と、
前記検出された燃焼重心位置に基づいて、燃焼状態を検出する燃焼状態検出手段と、
を含んで構成したことを特徴とする内燃機関の燃焼状態検出装置。

【請求項２】燃焼圧力を検出する燃焼圧力検出手段と、前記検出された燃焼圧力に基づいて、燃焼期間中の燃焼の重心に相当するクランク角度位置を燃焼重心位置として求める燃焼重心位置検出手段と、
運転状態に応じ、所望の燃焼状態が得られた場合の燃焼期間中の燃焼の重心に相当するクランク角度位置を目標重心位置として設定する目標重心位置設定手段と、
前記燃焼重心位置が、前記目標重心位置になるように、機関制御量をフィードバック制御する機関制御量フィードバック制御手段と、
を含んで構成したことを特徴とする内燃機関の制御装置。

【請求項３】機関排気系に介装された排気浄化触媒の活性状態を検出する触媒活性状態検出手段を備え、
前記触媒活性状態検出手段により触媒不活性が検出されたときに、前記目標重心位置設定手段により設定される目標重心位置を、通常時より燃焼行程終了側へ近づけることを特徴とする請求項２に記載の内燃機関の制御装置。

【請求項４】前記機関制御量が、点火時期であることを特徴とする請求項２または請求項３に記載の内燃機関の制御装置。

【請求項５】気筒毎に、請求項１に記載の装置を備えたことを特徴とする内燃機関の燃焼状態検出装置。

【請求項６】気筒毎に、請求項２～請求項４の何れか１つに記載の装置を備えたことを特徴とする内燃機関の制御装置。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は内燃機関の燃焼状態検出装置及びその装置を備えた内燃機関の制御装置に関する。詳しくは、内燃機関の燃焼状態の検出技術の改良に関し、また当該改良された検出技術に基づいて機関制御量を制御する内燃機関の制御装置の改良に関する。

【０００２】

【従来の技術】従来から、内燃機関の排気系に介装した排気浄化触媒を機関始動後早期から活性化させるようにして、始動後早期から大気中への排気有害成分（ＮＯｘ，ＣＯ，ＨＣ等）の排出量を低減することが行なわれている。その一例として、例えば、機関始動後所定期間内において、点火時期を一定量遅角させることで、燃焼状態を悪化させて排気温度を上昇させ、これにより排気浄化触媒の早期活性化を図ろうとするものがある。

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【０００３】

【発明が解決しようとする課題】しかしながら、上記従来の方法では、点火時期の遅角に対する機関の各気筒毎の排気温度（燃焼状態の変化）は、一律に同遅角量を与えても、実際には各気筒毎に、圧縮比，吸入空気流量，スワール等の吸気流れ，バルブタイミング等が異なるため、その気筒毎に異なることとなる。勿論、機関間におけるバラツキも存在するため、一定量の遅角量では、機関毎においても同様の問題がある。

【０００４】①即ち、一律の遅角量では、極度に燃焼が悪化する気筒があったりするので、これを避けようとすると、未だ限界点まで余裕の有る気筒が多数存在する等の気筒間（或いは機関間）バラツキが生じるため、効果的に排気温度を上昇させることができなかった。従って、各気筒毎（或いは各機関毎）に、燃焼の安定限界を確保しつつ最遅角できる限界点まで点火時期を遅角させるようにするのが、運転性，燃費，排気特性等を所定範囲内に確保しつつ、効果的に排気温度を上昇させることができるという点で望ましい。

【０００５】なお、かかる気筒間、機関間のバラツキによる問題は、点火時期の遅角制御に限らず、所望の燃焼状態が得られるとして設定された点火時期に制御した場合も同様に発生する。即ち、所望の燃焼状態が得られるとして設定された点火時期に制御したにも拘わらず、気筒間、機関間のバラツキによって、実際には所望の燃焼状態が得られない気筒が発生することになるからである。

【０００６】②そこで、上記①の問題を解決すべく、気筒毎（機関毎）に、限界点まで点火時期を遅角させる方法があるが、例えば、各気筒毎に筒内圧を測定して（機関間のバラツキを無くす場合には、１気筒でもよい）、図示平均有効圧力（ＩＭＥＰ，以下Ｐｉとも言う）を求め、このＰｉ値の変動に基づいて限界点を見出すものがある。

【０００７】しかしながら、このＰｉ値は、燃焼圧（筒内圧）の所定クランク角度区間の面積を求めた値であり、図７に示すように、点火時期を遅角させても、Ｐｉ値自体それほど大きく変化しないものであり、従ってＰｉ値の変動を検出しても点火時期遅角の限界点を高精度に検出することができないものであった。また、回転変動を検出し、その結果に基づいて、機関の点火時期遅角の限界点を見出すものもあるが、この場合は、直接燃焼状態を検出していないので、高精度に点火時期遅角の限界点を検出することができない。

【０００８】なお、このように点火時期遅角の限界点を見出すに限らず、図示平均有効圧力Ｐｉから燃焼安定度（即ち、Ｐｉ変動）を検出して、所定の安定度が得られるように、点火時期をフィードバック制御する場合等

も、そのＰｉ値の変動自体が小さいために、検出精度が低く制御精度が低くなるという問題がある。本発明は、上記①，②に記載した従来の実情に鑑みなされたもので、まず第１に、従来のＰｉ変動等に基づく燃焼状態検出手法に対して、

ａ．より高精度に燃焼状態を検出できる内燃機関の燃焼状態検出装置を提供すること、を目的とし、第２に、

ｂ．上記燃焼状態検出装置を利用して、所望の燃焼状態が得られるように、点火時期（但し、これに限らず、燃料供給量，供給時期，ＥＧＲ量等の機関制御量であってよい）をフィードバック制御する内燃機関の制御装置を提供すること、を目的とする。

【０００９】加えて、上記制御装置を用いて、触媒不活性時に、限界点近くで燃焼状態させ排気温度を上昇させて、以って排気浄化触媒の早期活性化を図り排気有害成分の排出を最大限低減できるようにすることを目的とすると共に、上記各装置を気筒毎に設けることで、更なる検出精度・制御精度等の向上を図ることを目的とする。

【００１０】

【課題を解決するための手段】そのため請求項１の発明にかかる内燃機関の燃焼状態検出装置は、図１に示すように、燃焼圧力を検出する燃焼圧力検出手段と、前記検出された燃焼圧力に基づいて、燃焼期間中の燃焼の重心に相当するクランク角度位置を燃焼重心位置として求める燃焼重心位置検出手段と、前記検出された燃焼重心位置に基づいて、燃焼状態を検出する燃焼状態検出手段と、を含んで構成した。

【００１１】請求項２に記載の発明にかかる内燃機関の制御装置は、図２に示すように、燃焼圧力を検出する燃焼圧力検出手段と、前記検出された燃焼圧力に基づいて、燃焼期間中の燃焼の重心に相当するクランク角度位置を燃焼重心位置として求める燃焼重心位置検出手段と、運転状態に応じ、所望の燃焼状態が得られた場合の燃焼期間中の燃焼の重心に相当するクランク角度位置を目標重心位置として設定する目標重心位置設定手段と、前記燃焼重心位置が、前記目標重心位置になるように、機関制御量をフィードバック制御する機関制御量フィードバック制御手段と、を含んで構成した。

【００１２】なお、請求項３に記載の発明では、機関排気系に介装された排気浄化触媒の活性状態を検出する触媒活性状態検出手段を備え、前記触媒活性状態検出手段により触媒不活性が検出されたときに、前記目標重心位置設定手段により設定される目標重心位置を、通常時より燃焼行程終了側へ近づけるように構成した。

【００１３】請求項４に記載の発明では、前記機関制御量を、点火時期として構成した。請求項５，６に記載の発明では、気筒毎に、上記各装置を備えるようにした。

【００１４】

【作用】請求項１に記載の発明にかかる内燃機関の燃焼状態検出装置では、燃焼状態の変化に対して比較的大き

く変化する燃焼期間中の燃焼の重心位置、即ち、燃焼圧に相関する値（燃焼圧そのものや図示平均有効圧力、或いは熱発生率等）の燃焼期間中の変化パターンのクランク角度或いは時間に対する重心位置、を検出し、当該検出された燃焼重心位置に基づいて（例えば、予め定めた所定の燃焼状態に対応する目標重心位置と比較することで）、燃焼状態を検出するようにする。これにより、従来のように、燃焼状態の変化に対して比較的小さな変化としてしか現れない図示平均有効圧力の変動等に基づいて燃焼状態を検出するものに較べ、より高精度に機関の燃焼状態を検出することができる。なお、燃焼重心位置は、１燃焼サイクルのものに限らず、複数燃焼サイクルの重心位置を平均化したものでもよい。

【００１５】請求項２に記載の発明にかかる内燃機関の制御装置では、上記方法で検出された燃焼重心位置が目標重心位置と一致するように、機関制御量をフィードバック制御するようにしたので、機関間のバラツキがあっても、高精度に目標の燃焼状態を達成させることができる。例えば、機関始動後の触媒早期活性化のための点火時期遅角制御にあっては、所定の燃焼安定限度内で燃焼エネルギが最大に排気エネルギとなるように点火時期を制御し、通常点火時期制御にあっては、燃焼エネルギが有効に回転エネルギになるように点火時期を制御することで、所望の燃焼状態を達成できる。なお、請求項５に記載の発明のように各気筒において、上記制御を行なえば、機関間は勿論、気筒間のバラツキがあっても、高精度に気筒毎に目標の燃焼状態を達成させることができる。

【００１６】請求項３に記載の発明では、触媒不活性状態において、前記目標重心位置を、通常時より燃焼行程終了側へ近づけるようにしたので、始動後等の触媒不活性時に燃焼状態を所望まで悪化させて効果的に排気温度を上昇させることができるので、以って効果的に触媒の活性化を促進させることができ、排気有害成分の排出を最小に留めることができる。

【００１７】請求項４に記載の発明では、前記機関制御量を、点火時期として構成したので、応答性良く高精度に、目標燃焼状態に制御することが可能となる。

【００１８】

【実施例】以下に、本発明の一実施例について説明する。本発明にかかる実施例のシステム概略図である図３において、４気筒内燃機関１には、エアクリーナ２，スロットルチャンバ３，吸気マニホールド４を介して空気が吸入される。そして、機関１からの燃焼排気は、排気マニホールド５，排気ダクト６，排気浄化触媒としての三元触媒７，マフラー８等を介して大気中に排出される。なお、本実施例では三元触媒７を用いて説明するが、これに限らず酸化触媒、リーンＮＯｘ触媒等を備えるものであってもよい。

【００１９】前記スロットルチャンバ３には、図示しな

いアクセルペダルに連動して開閉するスロットル弁９が設けられており、このスロットル弁９によって機関１の吸入空気量が調整されるようになっている。また、各気筒（＃１～＃４）の燃焼室に臨ませてそれぞれ点火栓（図示省略）が装着されているが、かかる点火栓と対に、それぞれの気筒毎に筒内圧センサ10ａ～10ｄを設けてある。

【００２０】前記筒内圧センサ10ａ～10ｄは、実開昭６３－１７４３２号公報に開示されるような点火栓の座金として装着されるタイプの他、特開平４－８１５５７号公報に開示されるようなセンサ部を直接燃焼室内に臨ませて筒内圧を検出するタイプのものであっても良い。なお、機関間のバラツキを無くすことを目的とする場合には、何れか１気筒に筒内圧センサを取り付ければよい。

【００２１】また、機関１の図示しないカム軸には、カム軸の回転を介してクランク角を検出するクランク角センサ11が設けられている。このクランク角センサ11は、本実施例の４気筒機関１において、気筒間の行程位相差に相当するクランク角180°毎の基準角度信号ＲＥＦと、単位クランク角毎の単位角度信号ＰＯＳとをそれぞれ出力するセンサである。

【００２２】尚、前記基準角度信号ＲＥＦは、気筒判別が行なえるように、少なくとも特定１気筒に対応する検出信号がそのパルス幅等によって他の検出信号と区別できるようになっている。また、前記スロットル弁９の上流側には、機関１の吸入空気流量Ｑを検出するエアフローメータ13が設けられており、前記スロットル弁９には、該スロットル弁９の開度ＴＶＯを検出するポテンショメータ式のスロットルセンサ14が設けられている。

【００２３】さらに、機関１の冷却水温度を検出する水温センサ15が設けられている。前記筒内圧センサ10ａ～10ｄ，クランク角センサ11，エアフローメータ13，スロットルセンサ14，水温センサ15等の出力は、機関制御用として設けられたコントロールユニット12に出力される。マイクロコンピュータを内蔵した前記コントロールユニット12は、これらの入力信号に基づき運転状態を検出し、これに対応して、図示しない燃料噴射弁による燃料噴射量，噴射時期を制御すると共に、点火栓による点火時期を制御する。

【００２４】ここで、本実施例におけるコントロールユニット12が行なう点火時期制御（燃焼状態検出制御を含む）について、図４のフローチャートを参照して説明する。尚、本実施例において、燃焼圧力検出手段，燃焼重心位置検出手段，燃焼状態検出手段，目標重心位置設定手段，機関制御量フィードバック制御手段，触媒活性状態検出手段としての各機能は、コントロールユニット12がソフトウェア的に備えている。

【００２５】図４のフローチャートにおいて、ステップ（図では、Ｓとしてある。以下同様）１では、水温センサ15の検出した機関冷却水温が、所定範囲（例えば、１５～４０°Ｃ）内にあるか否かを判断する。ＹＥＳであれば、触媒早期活性化のための点火時期遅角を行なうべく、ステップ２へ進む。ＮＯであればステップ３へ進む。即ち、所定範囲より高温側は始動後所定期間経過した状態或いはリスタート時等であり、機関温度が高く三元触媒７も既に活性化している（或いは極めて活性化し易い状態にある）と判断し、この場合には遅角制御を行なう必要がないので、運転性，燃費等を優先させる通常制御を行なわせるべく、ステップ３へ進ませる。そして、所定範囲より低温側の極低温時は、遅角制御を行なうと、運転性（燃焼安定性）が許容限度を越えて悪化するので、かかる場合にも遅角制御を禁止して運転性を優先させるべく、ステップ３へ進ませる。当該ステップ１が、本発明の触媒活性状態検出手段として機能する。

【００２６】ステップ２では、触媒活性化促進のための点火時期の遅角制御を行なわせるために、目標重心クランク角度T_{SET}を「１５（deg ＡＴＤＣ）＋Ｋ」にセットする。なお、T_{SET}＝１５（deg ＡＴＤＣ）は、ＭＢＴ（Minimum Spark Advancefor Best Torque ）が得られる一例であり、ＫはＡＴＤＣ（上死点後）側の限界遅角設定量を示している。この目標重心クランク角度T_{SET}，Ｋは、機関毎、運転条件毎に設定される所望の値である。なお、ここでの目標重心クランク角度T_{SET}は、予め実験等により確認された値であって、点火時期を限界点に設定したときに得られる燃焼期間中の図示平均有効圧力の発生パターンの重心位置に対応するクランク角度である。

【００２７】ステップ３では、通常点火時期制御を行なわせるために、目標重心クランク角度T_{SET}を、例えば１５（deg ＡＴＤＣ）にセットする（ＭＢＴに制御することになる）。ここでの目標重心クランク角度T_{SET}は、予め実験等により確認された値であって、点火時期をＭＢＴに設定したときに得られる燃焼期間中の図示平均有効圧力の発生パターンの重心位置に対応するクランク角度である。

【００２８】上記ステップ２，３が、本発明の目標重心位置設定手段として機能する。ステップ４では、筒内圧センサ10ａ（或いは10ｂ～10ｄ）の検出信号をＡ／Ｄ変換する。なお、当該ステップ４以降のステップは、各気筒毎に実行するようにするのが最も精度がよい。当該ステップ４が、燃焼圧力検出手段に相当する。ステップ５では、フロー中に示すように、公知の方法で、ステップ４で得られた結果を用いて、図示平均有効圧力（Ｐｉ）を算出する。このＰｉの算出に用いるクランク角度区間は、燃焼圧の影響を受ける区間（即ち、吸排気行程等は除く）に限定するのが、計算時間、メモリ容量等の面で好ましい。

【００２９】ステップ６では、フロー中に示すように、ステップ５で算出した図示平均有効圧力（ＩＭＥＰ）の重心位置に対応する実際のクランク角度Ｔｐｉ（deg Ｃ

Ａ）を求める。かかる重心位置の算出方法は、公知の方法であってよい。ステップ５，６が、本発明の燃焼重心位置検出手段に相当する。なお、筒内圧力Ｐの燃焼期間中の生波形（或いはＡ／Ｄ変換後の波形）の重心位置を求めるようにしてもよいし、熱発生率パターンを求めその重心位置を求めるようにしてもよい。

【００３０】ステップ７では、ステップ２或いはステップ３でセットした目標重心クランク角度T_{SET}と、実際の重心位置クランク角度Ｔｐｉと、を比較する。T_{SET}＝Ｔｐｉであれば、現在のＰｉの重心位置は目標重心位置に一致し、良好に目標とする燃焼状態、換言すれば目標点火時期が得られていると判断し、本フローを終了する。

【００３１】T_{SET}＞Ｔｐｉであれば、現在のＰｉの重心位置は、目標の重心位置に対して上死点（ＴＤＣ）側にあると判断し、未だ目標燃焼状態に到達していない（換言すれば、目標限界点まで点火時期を遅角できていない）と判断して、ステップ８へ進み、現在の点火時期ＡＤＵに対して所定量Ａ遅角（リタード）させて、本フローを終了する。

【００３２】一方、T_{SET}＜Ｔｐｉであれば、現在のＰｉの重心位置は、目標の重心位置に対して下死点（ＢＤＣ）側にあると判断し、目標燃焼状態を越えて悪化した（換言すれば、点火時期を遅角し過ぎて目標限界点を越えた）と判断して、ステップ９へ進み、現在の点火時期ＡＤＵに対して所定量Ｂ進角（アドバンス）させて、本フローを終了する。なお、前記Ａ，Ｂは同量であってもよいし、異ならせてもよい。ただし、機関安定性を考慮すれば、Ａ≦Ｂが好ましい。

【００３３】上記ステップ７が、本発明の燃焼状態検出手段に相当する。このように、本実施例によれば、燃焼状態の変化に対して比較的大きく変化する「燃焼期間中の図示平均有効圧力（或いは燃焼圧波形、熱発生率）の発生パターンの重心位置Ｔｐｉ」を検出し、当該検出された重心位置Ｔｐｉと予め定めた目標重心位置T_{SET}とを比較することで燃焼状態を検出するようにしたので、従来のようにＰｉの変動等に基づいて燃焼状態を検出するものに較べ、より高精度に機関の燃焼状態を検出することができる。

【００３４】また、この検出された重心位置Ｔｐｉが目標重心位置T_{SET}と一致するように（機関始動後の触媒早期活性化のための点火時期遅角制御にあっては、所定の燃焼安定限度内で燃焼エネルギが最大に排気エネルギとなるように。通常点火時期制御にあっては、燃焼エネルギが有効に回転エネルギになるように。）、点火時期をフィードバック制御するようにしたので、機関間のバラツキや気筒間バラツキがあっても、高精度に目標の燃焼状態を達成させることができる。

【００３５】なお、本実施例では、触媒不活性状態において、上記方法による点火時期の遅角制御を行なわせるようにしたので、例えば、始動後等において効果的に三元触媒７の早期活性を促進させることができるので、始動後早期から排気有害成分の排出を低減することができる。ところで、本実施例では、触媒不活性状態を冷却水温に基づいて検出するようにしたが、触媒温度を直接検出するようにしてもよいし、極低温時を除いて（例えば水温が１５度より低い場合）始動後予め定めた所定期間内において触媒が不活性状態であると擬制するようにしてもよい。また、始動時に極低温である場合には、始動後所定期間通常制御を行い、その後所定期間内において、点火時期の遅角（リタード）制御を行なうようにすることもできる（図６参照）。

【００３６】また、本実施例では、燃焼状態を制御する因子として点火時期（比較的制御が簡単で応答性が高いため）を代表して説明してきたが、燃料供給量、燃料供給時期、吸入空気流量（この場合、燃料供給量は固定する）、ＥＧＲ量、パージガス量等を制御するようにしてもよい。

【００３７】

【発明の効果】以上説明したように、請求項１の発明にかかる内燃機関の燃焼状態検出装置によれば、燃焼状態の変化に対して比較的大きく変化する燃焼期間中の燃焼の重心位置を検出し、当該検出された燃焼重心位置に基づいて燃焼状態を検出するようにしたので、高精度に機関の燃焼状態を検出することができる。

【００３８】請求項２に記載の発明にかかる内燃機関の制御装置によれば、上記方法で検出された燃焼重心位置が目標重心位置と一致するように、機関制御量をフィードバック制御するようにしたので、機関間のバラツキがあっても、高精度に目標の燃焼状態を達成させることができる。なお、請求項５に記載の発明のように各気筒において、上記制御を行なえば、機関間は勿論、気筒間のバラツキがあっても、高精度に気筒毎に目標の燃焼状態を達成させることができる。

【００３９】請求項３に記載の発明によれば、触媒不活性状態において、前記目標重心位置を、通常時より燃焼行程終了側へ近づけるようにしたので、始動後等の触媒不活性時に燃焼状態を所望まで悪化させて効果的に排気温度を上昇させることができるので、以って効果的に触媒の活性化を促進させることができ、排気有害成分の排出を最小に留めることができる。

【００４０】請求項４に記載の発明によれば、前記機関制御量を、点火時期として構成したので、応答性良く高精度に、目標燃焼状態に制御することが可能となる。

【図面の簡単な説明】

【図１】請求項１に記載の発明のブロック図。

【図２】請求項２に記載の発明のブロック図。

【図３】本発明の第１の実施例を示すシステム概略図。

【図４】同上実施例の点火時期制御を示すフローチャート。

【図５】同上実施例の点火時期制御の作用を説明する図。

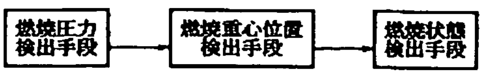
【図６】同上実施例の点火時期遅角期間を説明するタイムチャート。

【図７】従来の問題を説明する図。

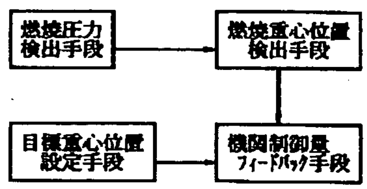
【符号の説明】

1	内燃機関
7	三元触媒
10a〜10d	筒内圧センサ
11	クランク角センサ
12	コントロールユニット
15	水温センサ

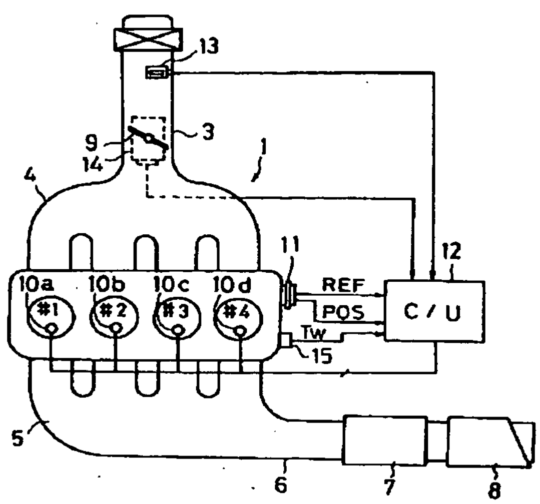
【図１】



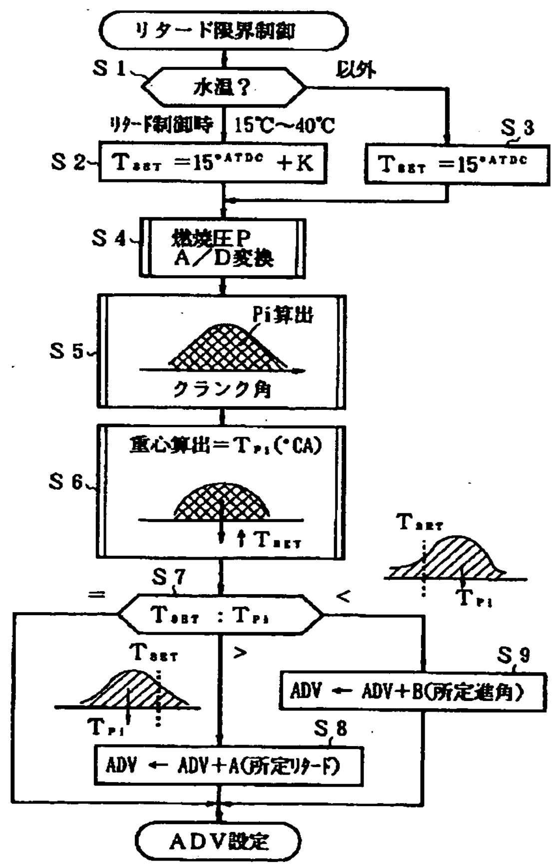
【図２】



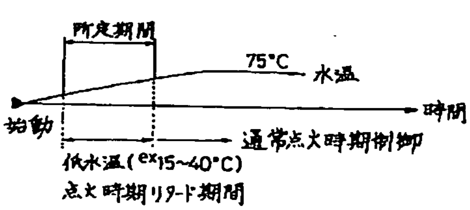
【図３】



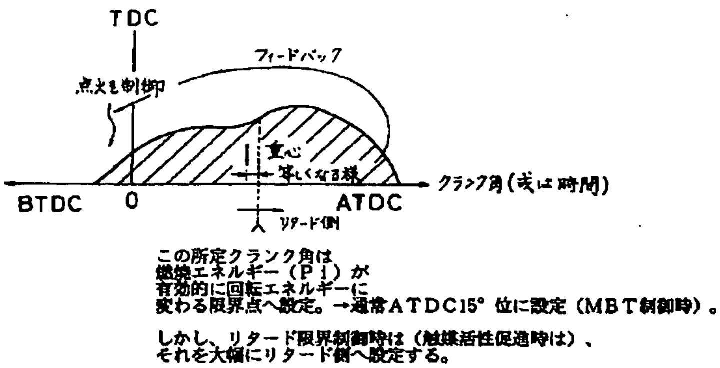
【図４】



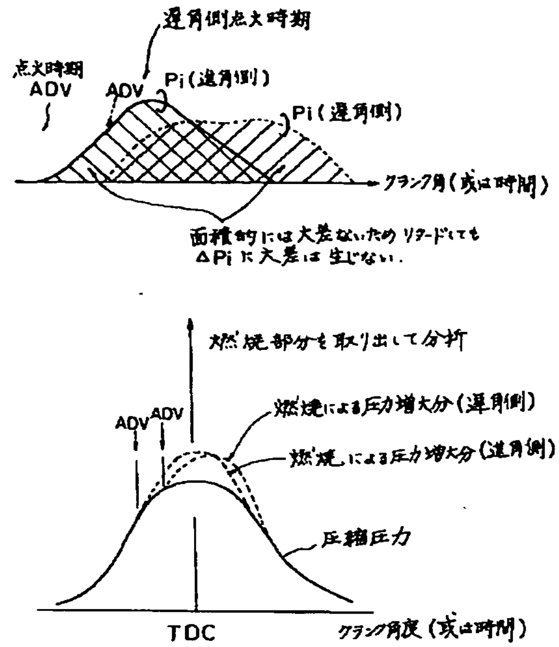
【図６】



【図５】


TDC
フィードバック
点火を制御
重心
等しくなる様
BTDC
0
ATDC
クランク角（或は時間）
リタード側
この所定クランク角は
燃焼エネルギー（Ｐｉ）が
有効的に回転エネルギーに
変わる限界点へ設定。→通常ＡＴＤＣ15° 位に設定（ＭＢＴ制御時）。
しかし、リタード限界制御時は（触媒活性促進時は）、
それを大幅にリタード側へ設定する。

【図７】


遅角側点火時期
点火時期
ADV
ADV
Pi（進角側）
Pi（遅角側）
クランク角（或は時間）
面積的には大差ないため リタードしても
ΔPi に大差は生じない.
燃焼部分を取り出して分析
ADV
ADV
燃焼による圧力増大分（遅角側）
燃焼による圧力増大分（進角側）
圧縮圧力
TDC
クランク角度（或は時間）